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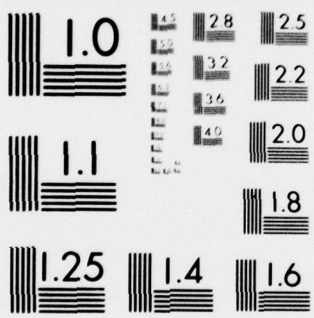
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Report 1978-6

SPATIAL ORIENTATION FROM HIGH VELOCITY BLUR PATTERNS

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This final report summarizes the results of eight investigations into human ability to detect and utilize the information found in blur patterns. These patterns of streaks formed by high speed motion are potentially useful orientation aids.

In these studies considerable human sensitivity was demonstrated to the parameters of divergence, curvature, curvature change and divergence change. Six technical reports are cited which discuss these results in detail.

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TO: Chief of Naval Research, Arlington, VA. 22217

Attention: Engineering Psychology Programs, Code 455

Drs. M. A. Tolcott and J. J. O'Hare

FROM: Thomas L. Harrington, Department of Psychology

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SUBJECT: Final report of work completed under the support of Contract N00014-76-C-0398, Work Unit Number NR 197-034, between the University of Nevada, Reno and the Engineering Psychology Programs, Office of Naval Research.

I. This constitutes a final report of work completed under the support of Contract N00014-76-C-0398, Work Unit Number NR 197-034, between the University of Nevada, Reno and the Engineering Psychology Programs, Office of Naval Research. The contract was initiated 1 September 1975, and was terminated 30 June 1978.

II. The mission of this contract was to conduct research to determine human ability to process the information contained in high-velocity motion-produced blur patterns. During the two-and-a-half years of the contracts existence six technical reports were completed and distributed detailing the results of the experiments and the investigations completed.

A list of these reports is attached as well as a list of the individuals associated with the project.

III. The research supported by the contract is summarized on the following pages.

The usual conceptions of visual orientation by a moving observer regard textural elements as though they provided the same visual stimulation that they do under conditions of static viewing. Actually texture in motion may lose many of its static characteristics but it gains important new motion-related parameters which emerge as direct consequences of the motion itself and the nature of the visual system. Specifically, points of light and dark in the "static" domain are transformed into streaks called motion bands or blur lines in the motion domain because of persistence in the visual system. A stationary line to the visual system, is a simultaneously-stimulated row of retinal points but because of temporal "slack" in the photoreceptors and in the succeeding neural elements and their interconnections, there is a great deal of tolerance in how simultaneous the stimulation must be. As a result, a single point in light or dark moving across the retina can stimulate successive locations quickly enough together that the visual impression is given of a line dragging along behind the point. The length of this line depends on the velocity of the point, its intensity, contrast, hue, context, state of dark adaptation of the eye, etc. The slope of this blur line will of course depend on the direction of movement of the point on the retina.

Thus a textured field, to a moving observer's visual system, is a field of variously sloped and curved blur lines. The motion-related information in these "blur patterns" is not in terms of motion of textural elements in time *per se*. Rather, at each separate moment, each blur line in the blur pattern displays the motion history of the element that produced it by virtue of its own characteristic shape and the observer is left processing a sort of time-varying stabilized image of variously curved and diverged stationary "lines."

Motion-produced "blur patterns" are commonly experienced, especially by pilots of rapidly moving vehicles, yet little research has been done until now on human processing of the information they convey. Research on very rapid visual transformations has significance in relation to theories of motion and form perception, as well as in practical applications to vehicle control. Psychophysical information about fast-motion vision could be used to maximize human visual performance in high-velocity situations and to improve the design of simulators, of motion monitors, and of piloted displays.

DETECTION OF DIVERGENCE

The experiments reported here demonstrated the sensitivity of the human visual system to the rapidly-moving divergence information in blur patterns and also demonstrated successful use of that information for surface orientation by human observers. Divergence thresholds were determined for nine locations in the visual field at three velocities; observers also used the divergence information to orient a surface to correspond with the degree of slant displayed in the blur patterns. Divergence was defined here in terms of the display itself; that is, divergence angle was defined as the angle between the right and left outermost lines possible in any given display. Divergence thresholds were measured in terms of the smallest divergence angle observers were able to recognize as differing from zero where zero corresponded to all the lines in the display being parallel.

Individual differences were great on these tasks. Those observers with lower thresholds for divergence judgments also tended to be the ones who could orient more successfully, and it is believed that a test based on blur pattern perception might be a useful adjunct to a pilot screening battery.

Having the blur pattern in the center of his visual field allows the observer to make the most efficient use of blur pattern information. Mean divergence thresholds for a central fixation point were 3.2°, suggesting a relatively high level of sensitivity. When the display is viewed further toward the periphery of the visual field, sensitivity drops but it is still high enough for blur patterns to provide useful information. Divergence threshold values around the fovea 20° out are 5.1°, 40° out are 7.1° and 75° out are 11.8°.

Performance at the three different angular velocities of 20, 40, and 80°/sec was equally good. This suggests the possibility that it may be possible to simulate or display directional information without regard to the velocity of the craft.

The number of elements composing the display, 16 or 32 elements for each 5" diameter video display frame, did not make any difference in terms of the threshold values obtained or in the observer's ability to orient.

Stimuli created by electronic means and employing only pure divergence did not differ from "natural" stimuli created by optical means and having gradients of element velocity, element size and element density existing along with

divergence. Again this result might permit simplification of display parameters for simulation and remote piloted displays.

Observers demonstrated an ability to use blur pattern information successfully for surface orientation but they also demonstrated a tendency to underestimate surface slant, a factor which might require exaggeration of some display parameters when these are planned for simulation purposes.

Practice greatly increased sensitivity to divergence information, and this would suggest the desirability of supplying training to those who might need blur pattern information when operating under difficult conditions (Report 1977-1).

DETECTION OF CURVATURE

One of the most important types of blur pattern information is found in the curvature which is typically present in all parts of the pattern whenever the observer moves to the left or right, or moves up or down, in any departure from straight and level motion over a flat surface.

The purpose of this investigation was to determine human thresholds for curvature in 16-element blur pattern displays in order to 1) learn more about the blur pattern processing capabilities of the visual system, 2) provide information for display design information, and 3) determine conditions under which blur pattern curvature would be a valuable orientation aid.

Ordinarily the fovea tracks a moving surface whereas the periphery does not; therefore, blurring is more often found off fovea. Also the fovea represents a very small percentage of our visual fields. Accordingly thresholds were measured on eight peripheral retinal loci.

The results showed that curvature in blur patterns is potentially useable in a wide range of situations. Thresholds were found to be in the same general range as those measured for curvature in stationary line segments.

Peripheral viewing did decrease curvature sensitivity as a direct function of distance from the fovea but not to the extreme degree that it does for visual acuity and peripheral sensitivity was seen as adequate for use in many conditions of blur pattern-based orientation (Report 1978-1).

DETECTION OF CURVATURE CHANGE

When a craft departs from moving straight and level over a flat surface or when the surface is not flat, the motion-produced visual blur patterns that the operator sees change in terms of their curvature. Since it had been demonstrated in the previous experiment that human observers are quite sensitive to blur pattern curvature, this experiment tested whether observers could respond to blur pattern curvature change at a level of sensitivity that would allow them to detect corresponding changes in path of flight and in terrain height and therefore use these cues for improved orientation.

Two retinal loci were investigated (foveal and 30°-peripheral). Also to fully characterize the response to these patterns which flowed downward and also oscillated sinusoidally side-to-side, the display used three different vertical velocities (4, 8 and 16°/sec) and five different frequencies of horizontal oscillation (1/4, 1/2, 1, 2, and 4 hz).

The major finding was that with our electronically generated 16-element synthetic blur pattern display, sensitivity to curvature change was adequate to be quite useful in assessing aspects of one's motion relative to the ground. The performance for the foveal-viewing conditon was superior but the peripheral condition also indicated potentially useful sensitivity levels.

The results also indicated the slower-moving patterns were more effective bearers of curvature change information, as were rapidly oscillating ones (Report 1978-2).

DETECTION OF CURVATURE CHANGE WITH REFERENCE GRATINGS

The purpose of this study was to determine whether the detection of blur pattern curvature change, studied in a previous experiment, would be enhanced if stationary reference lines were superimposed on the blur pattern.

Reference lines were oriented in three ways, parallel, perpendicular, and at 45° to the direction of element flow. Patterns were viewed foveally or with peripheral vision.

With the 16-element oscilloscope patterns that were used here there was only a small enhancement of curvature change detection under some conditions. It was felt, however, based on observations of naturally-occurring blur

patterns, that if the density of elements had been greater, considerably more effect might have been found. It appears that a motion display of the type used here does not profit from the particular type of reference grid that was used. Further experimentation is indicated (Report 1978-3).

DETECTION OF DIVERGENCE CHANGE

Unless an observer is looking straight to the side of his moving craft or perpendicularly to the path of a moving surface, typically the individual blur lines making up the pattern diverge or converge on his retina. Thus if the plane of motion changes, the divergence changes also and the divergence change becomes an important cue for orientation bearing information on motion parameters such as altitude change.

This experiment measured human thresholds for divergence change in the form of sinusoidal expansion and contraction of downward-moving 16-line element patterns on the face of an oscilloscope. The objective was to determine whether blur pattern divergence change sensitivity was acute enough to be of any practical value in visual orientation using display information.

In order to more fully characterize this potential visual capability thresholds were measured at five different frequencies of divergence change (1/4, 1/2, 1, 2 and 4 hz.) and at two different vertical pattern velocities (8 and 16°/sec). This also allowed separate assessments of the contributions of variables related to the form of the motion path and of those related to pattern motion *per se*. Also, a foveal and a peripheral retinal locus were studied and divergence changes were superimposed either upon parallel pattern motion or upon a pattern motion that diverged ten degrees at the display extremes, thus providing a check of the generalizability to other parts of the retina and of the visual field.

Observers proved to be very sensitive to divergence change and could easily use it for visual orientation improvement in a large number of situations. Sensitivity was greater for higher-frequency oscillations and for slower-moving patterns. A comparison of high-velocity and high-frequency patterns with low-velocity and low-frequency patterns (which would have the same element paths but slower motion) indicated that either motion sensitivity *per se* or from information such as path curvature could underly the obtained thresholds.

Foveal viewing provided the best sensitivity; however, the 30-degree peripheral condition was not far behind. Divergence change was only slightly more detectable when it was superimposed on parallel rather than diverging trajectories, indicating that divergence change in parts of the blur pattern that already have divergence is still useable (Report 1978-4).

PERCEPTION OF MOTION ORIENTATION USING DIVERGENCE, SIZE CHANGE AND VELOCITY CHANGE

As an observer moves relative to a textured surface such as the ground there is motion-related visual information available from that surface through three specific geometrical variables. These are vergence, size change and velocity change. As the textural elements move closer to the observer their paths of motion on the retina diverge. Movement away leads to convergence. Size of the elements also changes as a function of distance as does velocity. The purpose of this experiment was to determine the effectiveness of each variable and to assess their interactions in foveal and in peripheral viewing. The objective was to acquire information needed for movement display design as well as to discover more about the information humans use for orientation.

In this experiment displays were viewed in which the three variables were electronically separated and variously presented singly, in all possible pairs, and altogether in one display. The oscilloscope display consisted of 64 downward moving elements designed to simulate a moving surface tilted 75° away from the observer. Subjects communicated their perceptions of degree of perceived surface tilt at the top, bottom and middle of the display for the eight different combinations of variables. They also responded to apparent velocities of these same display areas.

The results showed that all three variables can lead to relatively reliable perceptions of motion in depth with velocity change being the most powerful determiner and with size change being the weakest. This finding was different than the results of a previous experiment on divergence in faster moving patterns where velocity change and size change appeared not to contribute. Foveal viewing was more accurate than peripheral viwing but peripheral performance nevertheless was found adequately consistent to function as an input channel in many orientation tasks.

Certain combinations of the variables led to perceptions of extreme warping and should be avoided in motion displays (Report 1978-5).

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